4 NUMERIC TARGETS

Water quality targets for mercury were calculated to protect beneficial uses of the water and aquatic resources of the Delta. The targets are intended to reduce the risks to humans and wildlife that consume fish and other aquatic organisms from the Delta that contain methylmercury. This chapter first describes the derivation of species-specific targets based on a suite of fish types to protect humans and wildlife. The Central Valley Water Board staff proposes three targets for the protection of human and wildlife health: 0.24 mg/kg (wet weight) in muscle tissue of large trophic level four (TL4) fish such as bass and catfish; 0.08 mg/kg (wet weight) in muscle tissue of large TL3 fish such as carp and salmon; and 0.03 mg/kg (wet weight) in whole trophic level 2 and 3 fish less than 50 mm in length. In addition, staff proposes an implementation goal of 0.24 mg/kg methylmercury, wet weight, in standard 350-mm largemouth bass. As described in Chapter 5, this implementation goal can be linked to aqueous methylmercury to develop an implementation goal for methylmercury in unfiltered ambient water, which in turn can be used to determine methylmercury source reductions needed to achieve the proposed target for methylmercury in fish.

In addition to addressing sources of methylmercury to the Delta, the Delta mercury control program addresses total mercury sources to the Delta and San Francisco Bay. The San Francisco Bay TMDL assigns a load reduction of 110 kg per year from the Central Valley (Johnson & Looker, 2004). As described in later chapters of this report, the mercury control program for the Delta is designed to achieve the total mercury load reduction required by the San Francisco Water Board, as well as to maintain compliance with the USEPA's CTR for total mercury in freshwater sources and to limit total mercury sources to the Delta to ensure that methylmercury levels in fish do not increase in the future.

4.1 Definition of a Numeric Target

Numeric targets are the specific goals for the TMDL that will enable the protection of the beneficial uses of the Delta and San Francisco Bay. The development of numeric targets involves the following elements:

- Identification of the target media and the basis for using the selected target media to interpret or apply applicable water quality standards.
- Identification of target levels for the selected target media and the technical basis for the target levels.
- Comparison of historical or existing conditions and desired future conditions for the target media selected for the TMDL.

4.2 Clean Water Act 303(d) Listing and Beneficial Use Impairment

The California Department of Health Services has issued health advisories recommending that consumers limit their consumption of striped bass and sturgeon from the Delta and Bay because of high methylmercury tissue concentrations (Section 2.4.1). The fish advisory resulted in the Central Valley and San Francisco Water Boards listing the Bay-Delta Estuary as impaired.

By definition, an impaired water body does not support all of its designated beneficial uses. Existing and potential beneficial uses are listed in Table 2.3 in Chapter 2. The Delta provides habitat for warm and cold water species of fish and the aquatic communities associated with them. In addition, the Delta and associated riparian areas provide valuable wildlife habitat. Beneficial uses that are impaired due to high mercury levels include commercial and sport fishing and wildlife habitat.

4.3 Selection of the Type of Target for the Delta

4.3.1 Fish Tissue

Measurements of mercury in the target media should be able to assess fairly directly whether beneficial uses are being met. Several media for numeric targets were considered, including sediment, water column and biota. The major beneficial use of the Delta that is currently unmet is its use as a safe fishery for humans and wildlife. A target of mercury in fish tissue was determined to be the most appropriate because it provides the most direct assessment of fishery conditions and improvement. Fish tissue data have been collected between 1969 and 2002 in the Delta. Existing data for fish species consumed by humans and wildlife provide a baseline against which future improvements can be measured.

Targets are developed for **methylmercury** in fish tissue because it is the most toxic form of mercury. It is also the form to which humans and wildlife may be exposed in the Delta at levels sufficient to cause adverse effects. The cost for methylmercury analysis is greater than that for total mercury; therefore, most data available are for total mercury in fish tissue. Independent research demonstrates that most mercury (85-100%) in fish muscle is methylmercury (Becker and Bigham, 1995; Slotton *et al.*, 2003). For the purposes of the TMDL, Central Valley Water Board staff assumes that all the mercury measured in fish is methylmercury.

4.3.2 San Francisco Bay Numeric Target

The Delta TMDL is also structured to meet the San Francisco Bay mercury TMDL's total mercury allocation for Central Valley outflows to the Bay. San Francisco Water Board staff developed a target for San Francisco Bay sediment mercury concentration of 0.2 mg/kg and assigned the Central Valley a five-year average total mercury load allocation of 330 kg/yr at Mallard Island or a decrease of 110 kg/yr in mercury sources to the Delta. The San Francisco Bay mercury TMDL staff report provides a detailed derivation of the San Francisco Bay sediment target and allocation for the Central Valley (Johnson & Looker, 2004). Strategies for reducing the total mercury loading to San Francisco Bay are discussed in Chapter 8 in this TMDL report and Chapter 4 in the Proposed Basin Plan Amendment draft staff report.

4.3.3 Water Criteria

The California Toxics Rule (CTR) mercury criterion applies to the Delta (see Section 2.3.2.2). This criterion of 50 ng/l total recoverable mercury in water is intended to protect the health of humans consuming contaminated organisms and drinking water. The CTR value may not be sufficiently protective of humans consuming fish from the Delta because of the low bioconcentration factors used to derive the CTR value. Central Valley Water Board staff considers fish tissue targets to be more stringent than the CTR criterion.[13] Although the CTR criterion may be less protective than the fish tissue targets discussed below, the TMDL was developed to comply with the CTR mercury criterion. Compliance with the CTR criterion through the TMDL is discussed in the total mercury source assessment (Chapter 7) and total mercury limits (Chapter 8) sections of this report.

4.4 Fish Tissue Target Equation and Development

Key variables that are incorporated into the calculation of fish tissue targets are:

- Acceptable daily dose level of methylmercury;
- Body weight (bwt) of the consumer;
- Trophic level or size of fish consumed; and
- Rate of fish consumption.

These components can be related using a basic equation (OEHHA, 2000; USEPA, 1995c) as follows.

Equation 4.1:

$$\frac{\text{Safe daily intake * Consumer's body weight}}{\text{Consumption rate}} = \text{Acceptable level of mercury in fish tissue}$$

At or below the safe daily intake of methylmercury, consumers are expected to be protected from adverse effects. An acceptable intake level is also called a reference dose (RfD). An RfD is expressed as an average daily rate (micrograms of mercury per kilogram body weight per day) of mercury intake. In general, an RfD is calculated by using studies of exposure in specific populations to determine a threshold level of exposure below which adverse effects did not occur. The threshold level is then divided by uncertainty factors that lower the value to the final reference dose. Uncertainty factors account for differences in metabolism and sensitivity between individuals, lack of toxicity information in available studies, or other unknowns.

In calculation of its recommended methylmercury criterion to protect human health, USEPA added a relative source contribution (RSC) component to the equation to account for methylmercury from other sources (USEPA, 2001). Humans are exposed to methylmercury from commercial fish as well as locally caught fish. Human intakes of methylmercury from all other sources (air, drinking water, soil, and foods other than fish and seafood) are considered negligible. The RSC represents that portion of methylmercury exposure that will not be controlled by cleanup actions directed to a particular water body. Because piscivorous wildlife species are assumed to obtain all of their fish or other aquatic prey from the local water body, no RSC adjustment is used for the wildlife calculations. As with humans, the direct intake of methylmercury by piscivorous wildlife from air or water is negligible relative to intake from fish and aquatic organisms (USEPA, 1997a).

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[13] The weighted average practical bioconcentration factor (PBCF) used to develop the CTR mercury criterion is 7342.6 (USEPA, 2000). For the Delta, bioaccumulation factors (BAF) for large trophic 4 fish are in the range of 50,000 to 300,000. These BAF are the ratios of mercury in fish to the concentration of total recoverable mercury in water. The Delta bioaccumulation factors indicate that piscivorous fish species in the Delta accumulate higher concentrations of mercury than USEPA's PBCF.

The consumption rate can be separated into rates of consumption of fish from each trophic level. Adjusting for multiple consumption rates and the RSC, the basic equation appears as follows.

Equation 4.2:

$$\frac{(\text{Safe intake} - \text{RSC}) * \text{body weight}}{(\text{CRate}_{TL2} + \text{CRate}_{TL3} + \text{CRate}_{TL4})} = \text{Acceptable level of mercury in Delta fish tissue}$$

Where: CRate_{TL2} = consumption rate of fish from Trophic Level 2
CRate_{TL3} = consumption rate of fish from Trophic Level 3
CRate_{TL4} = consumption rate of fish from Trophic Level 4

Safe levels of methylmercury in fish tissue that protect wildlife are presented first in this report, followed by the human health targets. The order of presentation and in-depth discussion of wildlife methodology are not intended to suggest greater importance of wildlife targets relative to human health targets. Rather, wildlife targets are discussed first because the safe fish tissue levels are based on average consumption rates that are assumed to be constant. Human consumption rates, however, vary widely by individual. For targets to protect human consumers, consumption rate options are incorporated into the calculation.

4.5 Wildlife Health Targets

Birds and mammals most likely at risk for mercury toxicity are primarily or exclusively piscivorous. Those identified for the Delta are: American mink, river otter, bald eagle, kingfisher, osprey, western grebe, common merganser, peregrine falcon, double crested cormorant, California least tern, and western snowy plover[14] (USEPA, 1997a; CDFG, 2002). Bald eagles, California least terns and peregrine falcons are listed by the State of California or by USEPA as either threatened or endangered species. The Delta is a foraging and possible wintering habitat for bald eagles (USFWS, 2004). California least terns also forage in the Delta. There is at least one nesting colony of these terns within the Delta (USFWS, 2004). Although most of the Delta habitat is unlike that preferred by peregrine falcons for nesting, several peregrine falcon pairs have nested on bridges in the area (Linthicum, 2003).

Acceptable fish tissue levels of mercury for wildlife species can be calculated using daily intake levels, body weights and consumption rates. Parameters needed to estimate daily methylmercury exposures and safe levels of methylmercury in prey for wildlife are given in Table 4.1. Mercury studies conducted in the laboratory and field are used to derive RfD for birds and mammalian wildlife. The following section uses these RfDs to calculate fish tissue targets to protect the health of wildlife in the Delta.

4.5.1 Reference Doses, Body Weights & Consumption Rates

The reference dose for mammalian wildlife species of 0.018 mg methylmercury/kg bwt/day is based on studies in which mink were fed methylmercury at varying doses and evaluated for neurological damage,

[14] The CDFG *California Wildlife Habitat Relationships* database also reports observations of brown pelicans and clapper rails in the Delta. Both of these species are federally listed as endangered and depend on the aquatic food web. However, it has been confirmed that brown pelicans and clapper rails prefer salt water habitats and are only occasional visitors to the Delta regions as discussed in this TMDL (Schwarzbach, 2003; CDFG, 2005). Peregrine falcon are included because they consume piscivorous waterfowl.

growth and survival (USEPA, 1995a; USEPA, 1997b). Studies of mallard growth and reproduction following methylmercury exposure were used to determine a methylmercury reference dose for birds of 0.021 mg/kg bwt/day (USEPA, 1997b).

Average body weights of adult females are used because the most sensitive endpoints of methylmercury toxicity are related to reproductive success. The USFWS provided guidance to Central Valley Water Board staff regarding the species of concern and their exposure parameters (USFWS, 2002, 2003 & 2004).

4.5.2 Safe Methylmercury Levels in Total Diet

Levels of mercury in fish tissue that would result in methylmercury intakes by piscivorous wildlife at or below safe intake levels are calculated in two steps. First, safe levels of methylmercury in the total diet of each wildlife species are calculated (Table 4.2). The total diet safe level represents the concentration of methylmercury, as an average in all prey consumed, needed to keep the organism's daily intake of methylmercury below the reference dose. Total diet safe levels were calculated using the exposure parameters for wildlife species and Equation 4.1. In the second step, the total diet safe level is translated into protective levels of methylmercury in various components of an organism's diet (Table 4.3). An example calculation of the total safe diet level for mink is shown below:

$$\frac{\text{Mammalian reference dose * Mink body weight}}{\text{Mink fish consumption rate}} = \text{Total diet safe level}$$

$$\frac{18\ \mu\text{g MeHg/kg day * 0.60 kg}}{140\ \text{g/day}} = 0.077\ \mu\text{g MeHg/g total diet (0.077 mg/kg)}$$

4.5.3 Calculation of Safe Fish Tissue Levels from Total Diet Values

Wildlife species consume fish and other aquatic prey from various size ranges and trophic levels. In the second step of wildlife target development, safe fish tissue levels are identified for different prey classifications. These classifications are termed "trophic level food groups". Table 4.3 shows safe fish tissue concentrations needed by the wildlife species and developed for prey within the following trophic level food groups: TL 2 fish less than 50 mm in length, TL2 and 3 fish of 50-150 mm, TL3 fish of 150-350 mm, and TL4 fish greater than 150 mm.

In cases in which an organism's prey is fairly uniform and from one trophic level, the total diet safe level becomes the average, safe tissue concentration. For organisms that feed from different trophic levels, the proportions of each trophic level in the diet (Table 4.1) are used to determine safe tissue levels for each component of the diet. The species whose prey falls generally into one size category are: mink, California least tern, western snowy plover, double crested cormorant, western grebe, kingfisher and

Table 4.1: Exposure Parameters for Fish-Eating Wildlife

Species (a)	Body weight (b)	Total Food Ingestion Rate (c)	Trophic Level 2 Aquatic Prey	Trophic Level 3 Aquatic Prey	Trophic Level 4 Aquatic Prey	Piscivorous Bird Prey	Omnivorous Bird Prey	Other Foods (d)	Size of Prey
	kg	g/day, wet wt	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	g/day, as % of diet	
Mink	0.60	140	-	140 (100%)	-	-	-	-	most prey 50-150mm; females catch smaller prey than males (USEPA, 1995b)
River otter	6.70	1124	-	899 (80%)	225 (20%)	-	-	-	heterogeneous, 20-500 mm (USEPA, 1995b); majority <150 mm but commonly catch large TL4 fish.
California least tern	0.045	31	-	31 (100%)	-	-	-	-	mostly < 50 cm, nearly all fish
Western snowy plover	0.041	33.3	8.3 (25%)	-	-	-	-	25 (75%)	mainly aquatic and terrestrial invertebrates. Assume TL2 aquatic prey is 25% of diet; (USFWS, 2003)
Belted kingfisher	0.15	68	-	68 (100%)	-	-		-	generally less than 105 mm; up to 180 mm (Hamas, 1994)
Common merganser (e)	1.23	302	-	302(100%)	-	-	-	-	most prey <150 mm (USEPA,1995b; Hatch & Weseloh, 1999)
Double-crested cormorant (f)	1.74	390	-	390 (100%)	-	-	-	-	generally 100-300 mm length; up to 360mm (Mallory & Metz, 1999)
Western grebe (g)	1.19	296	-	296 (100%)	-	-	-	-	USFWS assumed similar to merganser (USFWS, 2004)
Bald eagle (h)	5.25	566	-	328 (58%)	74 (13%)	28 (5%)	74 (13%)	62 (11%)	fish 75-500+ mm; most will be >150 mm (Jackman, 1999; USEPA, 1995b).
Osprey (i)	1.75	350	-	315 (90%)	35 (10%)	-	-	-	fish 100-450 mm; most will be >200 mm.
Peregrine falcon (j)	0.89	134	-	-	-	6.7 (5%)	13.4 (10%)	114 (85%)	Does not eat fish.

<u>Table 4.1 Footnotes</u>:

(a) Italics denote species listed as threatened or endangered by State or Federal authorities.
(b) Average female body weights are from *Trophic Level and Exposure Analyses for Selected Piscivorous Birds and Mammals Volume II* (USEPA, 1995b), USFWS (2003, 2004), and as noted below.
(c) Total food ingestion rates are from USEPA (1995b) and USFWS (2003; 2004) and as noted below.
(d) Other foods are mainly terrestrial mammal, bird, reptile and invertebrate prey that are presumed to provide negligible amounts of methylmercury.
(e) Merganser body weight and ingestion rate from Schwarzbach and others (2001).
(f) Cormorant body weight is the average for female birds cited in Hatch and Weseloh (1999). This paper also reports daily consumption at 20-25% of body mass. Total ingestion rate of 390 g/day is 22.5% of average female bodyweight.
(g) Female western grebe body weight from Storer and Nuechterlein (1992).
(h) Bald eagle parameters provided by the USFWS (2004). Diet of bald eagles in northern California includes fish, mammals and birds. Using dietary data from Jackman and others (1999), the USFWS estimated the average proportions of prey types. TL3 and TL4 fish comprised 58% and 13% of the total bald eagle diet, respectively. Piscivorous birds, such as gulls, grebes, and mergansers, comprised approximately 5% of the total diet. An additional 13% of the total diet was comprised of other aquatic birds, such as coots, that feed mainly on TL2 organisms. Bald eagles are scavengers and thus consume fish of large sizes (Jackman *et al.*, 1999).
(i) Osprey catch and eat large fish, the majority of which are >200 mm (USEPA, 1995b). In a water body where TL4 sport fish are readily available, osprey diet is assumed to be 10% TL4 fish (USFWS, 2002). Prey size is limited to the maximum size that an osprey can lift out of water.
(j) Peregrine falcons eat a wide variety of birds, including grebes, herons, shorebirds, mergansers, gulls and other birds that accumulate methylmercury from the aquatic food web. USFWS (2004) supports the assumption by Central Valley Water Board staff that approximately 15% of peregrine prey in the Delta area is comprised of piscivorous birds. See the appendices of the Cache Creek TMDL for Mercury for further analysis of peregrine prey and habitat. Available at: http://www.swrcb.ca.gov/rwqcb5/programs/tmdl/Cache-SulphurCreek/index.html.

Table 4.2: Concentrations of Methylmercury in Total Diet to Protect Delta Wildlife Species

Species	**RfD** (µg/kg bwt-day)	**Body Weight** (kg)	**Total Food Ingestion Rate** (g/day)	**Safe Methylmercury Concentration in Total Diet** (mg/kg in diet)
Mink	18	0.60	140	0.077
River otter	18	6.70	1124	0.11
California least tern	21	0.045	31	0.030
Western snowy plover	21	0.041	33.3	0.026
Belted kingfisher	21	0.15	68	0.046
Common merganser	21	1.23	302	0.086
Double-crested cormorant	21	1.74	390	0.094
Western grebe	21	1.19	296	0.084
Bald eagle	21	5.25	566	0.20
Osprey	21	1.75	350	0.11
Peregrine falcon	21	0.89	134	0.14

Table 4.3: Safe Concentrations of Methylmercury in Fish (mg/kg) by Trophic Level to Protect Wildlife

Species (a)	**TL 2, < 50 mm**	**TL 2-3, 50-150 mm**	**TL 3, 150-350 mm**	**TL 4, 150-350 mm**	**TL 3, >150 mm**	**TL 4, >150 mm**
Mink		0.08				
River otter		0.04		0.36		
California least tern	0.03					
Western snowy plover (b)	0.10					
Belted kingfisher		0.05				
Double-crested cormorant		0.09				
Common merganser			0.09			
Western grebe			0.08			
Osprey			0.09	0.26		
Bald eagle (c)					0.11	0.31
Peregrine falcon (d)			(0.17)			

(a) Italics denote species that are listed as threatened or endangered by federal or State authorities.
(b) The snowy plover safe level should be applied to TL2/3 aquatic invertebrates, such as small clams, crabs, polychaetes and amphipods.
(c) To avoid exceeding the bald eagle wildlife value, safe concentrations must be attained in birds as well as fish eaten by bald eagles. The safe levels for average mercury concentrations in omnivorous and piscivorous bird prey are 0.19 and 1.35 mg/kg, respectively. Because bald eagles are scavengers, there is no upper size limit on fish eaten by these birds.
(d) Parentheses denote the TL3 fish level corresponding to the piscivorous bird safe concentration for peregrines. For birds eaten by peregrine falcons, the average concentrations should not exceed 2.2 mg/kg in piscivorous bird prey, respectively.

common merganser. For these species, the total diet safe level becomes the safe fish tissue level matched to the size and trophic level of prey consumed.

Average, safe fish tissue concentrations for kingfisher, cormorant and mink were determined for the food group size range of 50-150 mm. Although kingfishers typically consume fish less than 105 mm in length, they can eat fish as long as 180 mm (Hamas, 1994; USEPA, 1995b). The range for cormorant prey is 30 to 400 mm, with most fish eaten being less than 150 mm (Hatch and Weseloh, 1999). Most fish caught by mink are in the range of 50-150 mm (USEPA, 1995b). As the size ranges of prey caught by these three species are similar, one category of TL2/3 fish is appropriate for their protection (USFWS, 2004).

A second food group of TL3 fish in the range of 150-350 mm incorporates safe fish tissue concentrations for prey of common mergansers and western grebes. Most prey caught by mergansers is in the range of 100-300 mm, with catches of fish up to 360 mm observed (Mallory and Metz, 1999). Because body size and foraging strategy of western grebes are similar to those of the merganser, staff assumed the same size range for grebe prey (USFWS, 2004).

Otter, bald eagle and osprey eat fish from multiple trophic level food groups. Methylmercury concentrations vary as a function of size and trophic level of prey. Therefore, different trophic levels of prey will have different acceptable concentrations of methylmercury. For these wildlife species, the total diet safe level (TDSL) can be described as:

Equation 4.3:

$$TDSL = (\%\ diet\ TL_2 * TL2_{conc}) + (\%\ diet\ TL_3 * TL3_{conc}) + (\%\ diet\ TL_4 * TL4_{conc})$$

Where: $\%\ diet\ TL_2$ = percent of trophic level 2 biota in diet
$\%\ diet\ TL_3$ = percent of trophic level 3 biota in diet
$\%\ diet\ TL_4$ = percent of trophic level 4 biota in diet
$TL2_{conc}$ = concentration of methylmercury in TL2 biota
$TL3_{conc}$ = concentration of methylmercury in TL3 biota
$TL4_{conc}$ = concentration of methylmercury in TL4 biota

In order to solve the above equation for the desired concentrations in TL2, TL3 and TL4 biota, concentrations in two trophic levels are put in terms of the concentration in the lowest trophic level. Equation 4.3 is then rearranged to solve for the lowest trophic level concentration.

In order to express the concentration in a higher trophic level (i.e., TL4) in terms of TL2 concentrations, staff used two types of translators: food chain multipliers (FCM) and trophic level ratios (TLR).[15] FCM and TLR used in the calculation of Delta wildlife targets are shown in Table 4.4. Where possible, site-specific, existing fish concentration data was used to develop the ratios. A similar table of safe fish tissue concentrations to protect wildlife species using a national average bioaccumulation factor (BAF) between TL3 and TL4 of five is presented in Chapter 6 of Mercury Study Report to Congress Vol. 7 (USEPA, 1997b). Details regarding the calculation of the translators and their use were provided by the USFWS (2003 & 2004).

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[15] A food chain multiplier (FCM) is the ratio of methylmercury concentrations in fish of different trophic levels. A FCM represents the biomagnification of mercury between 2 successive levels of the food chain. The FCM is determined using mercury concentration data in fish in a predator-prey relationship. Example: the FCM for trophic level 4 fish is the ratio of methylmercury in large TL4 fish to methylmercury in small TL3 fish.

A trophic level ratio (TLR) is the ratio of methylmercury concentrations in fish of different trophic levels, but is derived using data for fish in the same size classification. For example, an osprey may consume sunfish (TL3) and bass (TL4). A 350 mm sunfish, though, is too large to be preyed upon by an equivalently-sized smallmouth bass. Therefore, the ratio of mercury concentration in TL4 to TL3 fish eaten by osprey is termed a TLR rather than a FCM.

Table 4.4: Food Chain Multipliers and Trophic Level Ratios for Delta Wildlife Target Development

Translator	Value	Source	Relevant Wildlife Species (a)
Trophic Level Ratio (TLR)			
TLR 4/3	3.0	Ratio between existing MeHg concentrations in large TL4 fish (150-350 mm length) and large TL3 fish (150-350 mm length). Calculated from Delta-wide average fish tissue levels; see Appendix B.	Bald eagle, osprey
Food Chain Multipliers (FCM)			
FCM 4/3	8.1	Ratio between existing MeHg concentrations in large TL4 fish (150-350 mm length) and small TL3 fish (50-150 mm). Calculated from Delta-wide average fish tissue levels; see Appendix B.	River otter
FCM 3/2	5.7	Ratio between MeHg concentrations in large TL3 fish and small TL2 fish. From USFWS (2004) based on national averages.	Bald eagle, peregrine falcon
FCM piscivorous birds (FCM PB)	12.5	Ratio between MeHg in piscivorous bird tissue and in small TL3 prey fish. From USFWS (2003).	Bald eagle, peregrine falcon
FCM omnivorous birds (FCM OB)	10	Ratio between MeHg in omnivorous bird tissue and in small, TL2/3 prey fish and other aquatic organisms. From USFWS (2003).	Bald eagle, peregrine falcon

(a) Wildlife species for which the translator is used to determine safe tissue levels

4.5.3.1 River Otter Safe Tissue Levels

To calculate the safe concentrations for otter, the safe concentrations in TL3 and TL4 fish need to be determined. In order to solve for these two variables using Equation 4.3, the TL4 fish concentration is expressed in terms of the TL3 fish concentration. River otters eat a wide range of prey sizes. Large fish in the otter diet likely prey on small fish that otter also eat. Therefore, the TL4 variable is expressed using the TL3 concentration and a food chain multiplier (FCM 4/3). From the Delta field data, staff determined that the methylmercury concentration in large TL4 fish is 8.1 times the concentration in small TL3 fish. Safe tissue levels in TL3 and TL4 fish for otter are determined by:

$$TDSL_{otter} = (\%\ dietTL_3 * TL3_{conc}) + (\%\ dietTL_4 * TL4_{conc})$$

$$\textit{Where: } TL4_{conc} = TL3_{conc} * FCM\ 4/3$$

$$0.107\text{ mg/kg} = (0.8 * TL3_{conc}) + (0.2 * 8.1 * TL3_{conc})$$

Solving for $TL3_{conc}$:

$$TL3_{conc} = 0.04\text{ mg MeHg/kg fish}$$

$$TL4_{conc} = 0.04\text{ mg/kg} * 8.1 = 0.36\text{ mg MeHg/kg fish}$$

4.5.3.2 *Osprey safe tissue levels*

Safe methylmercury tissue levels for osprey are calculated like those for river otter, with the exception of the trophic level translator. Trophic level 3 and 4 fish eaten by osprey tend to be of similar sizes. Because there is not a food chain relationship between similarly sized fish, the osprey values are calculated using a trophic level ratio (TLR 4/3). On average in the Delta, methylmercury levels in large TL4 fish are 3.0 times the levels in large TL3 fish.

$$TDSL_{osprey} = (\%\ dietTL_3 * TL3_{conc}) + (\%\ dietTL_4 * TL4_{conc})$$

Where: $TL4_{conc} = TL3_{conc} * TLR\ 4/3$

$$0.105\ mg/kg = (0.9 * TL3_{conc}) + (0.1 * 3.0 * TL3_{conc})$$

Solving for $TL3_{conc}$:

$$TL3_{conc} = 0.088\ mg\ MeHg/kg\ fish$$

$$TL4_{conc} = 0.088\ mg/kg * 3.0 = 0.26\ mg\ MeHg/kg\ fish$$

4.5.3.3 *Bald Eagle Safe Tissue Levels*

Calculation of methylmercury tissue levels for bald eagle is slightly more complicated because bald eagles consume omnivorous birds (OB), piscivorous birds (PB), and fish. The omnivorous birds of concern in the bald eagle diet feed on trophic level 2 aquatic prey (mostly invertebrates). To solve the equation, safe tissue concentrations in the other eagle prey types are expressed in terms of the lowest food chain level (TL2) common to all prey types (USFWS, 2004). To translate the TL2 concentration into the piscivorous bird safe level, staff used the food chain multiplier for TL3 small fish (FCM 3/2) and the food chain multiplier relating piscivorous birds and small TL3 fish (FCM PB). Like osprey, bald eagles tend to eat TL3 and TL4 fish of similar size, hence the use of the TL4/3 ratio.

$$TDSL_{bald\ eagle} = (\%\ dietTL_3 * TL3_{conc}) + (\%\ dietTL_4 * TL4_{conc}) + (\%diet_{OB} * OB_{conc}) + (\%diet_{PB} * PB_{conc})$$

Where: $TL3_{conc\ large\ fish} = TL2_{conc} * FCM\ 3/2$

$$TL4_{conc\ large\ fish} = TL2_{conc} * FCM\ 3/2 * TL\ 4/3$$

$$OB_{conc} = TL2_{conc} * FCM\ OB$$

$$PB_{conc} = TL2_{conc} * FCM\ 3/2 * FCM\ PB$$

$$0.195\ mg/kg = (0.58*5.7*TL2_{conc}) + (0.13*5.7*3.0*TL2_{conc}) + (0.13*10*TL2_{conc}) + (0.05*5.7*12.5*TL2_{conc})$$

Solving for $TL2_{conc}$:

$$TL2_{conc} = 0.019 \text{ mg MeHg/kg fish} \quad \textit{(not eaten by eagles; used to determine other safe levels)}$$

$$TL3_{conc\ large\ fish} = 0.019 * 5.7 = 0.11 \text{ mg MeHg/kg fish}$$

$$TL4_{conc\ large\ fish} = 0.019 * 5.7 * 3.0 = 0.31 \text{ mg MeHg/kg fish}$$

$$OB_{conc} = 0.019 * 10 = 0.19 \text{ mg MeHg/kg omnivorous birds}$$

$$PB_{conc} = 0.019 * 5.7 * 12.5 = 1.35 \text{ mg MeHg/kg piscivorous birds}$$

4.5.3.4 Peregrine Falcon Safe Tissue Levels

Peregrine falcons consume almost exclusively avian prey, some of which is aquatic-dependent. To solve for safe concentrations in omnivorous and piscivorous bird prey, these terms are expressed as functions of the lowest trophic level common to the birds' food web, which is TL2 aquatic prey (USFWS, 2004).

$$TDSL_{peregrine} = (\%diet_{OB} * OB_{conc}) + (\%diet_{PB} * PB_{conc})$$

Where: $$OB_{conc} = TL2_{conc} * FCM\ OB$$

$$PB_{conc} = TL2_{conc} * FCM\ 3/2 * FCM\ PB$$

$$0.139 \text{ mg/kg} = (0.10 * 10 * TL2_{conc}) + (0.05 * 5.7 * 12.5 * TL2_{conc})$$

Solving for $TL2_{conc}$:

$$TL2_{conc} = 0.030 \text{ mg MeHg/kg fish} \quad \textit{(not eaten by peregrines; used to determine other safe levels)}$$

$$OB_{conc} = 0.030 * 10 = 0.30 \text{ mg MeHg/kg omnivorous birds}$$

$$PB_{conc} = 0.030 * 5.7 * 12.5 = 2.2 \text{ mg MeHg/kg piscivorous birds}$$

Note that the safe fish tissue levels in Table 4.3 are partially watershed-dependent and are specific to the Delta. The acceptable, average fish tissue concentrations for wildlife consuming from one trophic level will be consistent across different water bodies. This is because all of the parameters used to calculate the safe fish levels (species body weight, consumption rate and reference dose) were obtained from published literature and apply on a national or regional scale (Table 4.2). For species consuming fish from two trophic level classifications or piscivorous birds, translators (FCM or TLR) were used to calculate the safe concentrations in prey fish and piscivorous birds. These translators should be derived from site-specific data when possible and may differ between watersheds. For the Delta targets, the TLR and FCM between trophic level 4 and 3 fish were specific to the Delta. The FCMs for piscivorous birds, omnivorous birds and trophic level 3 fish were literature-derived average values.

Central Valley Water Board staff is not proposing safe tissue levels in piscivorous or omnivorous birds as TMDL targets. Data are lacking to compare safe levels in bird prey with existing conditions. By lowering methylmercury concentrations in fish and aquatic prey to safe levels shown in Table 4.3, staff anticipates that concentrations in birds feeding in the aquatic food web will decline to safe levels as well. In particular for peregrine falcon, the desired safe level in piscivorous birds is 2.2 mg/kg. Dividing the safe piscivorous bird level by 12.5 (FCM PB) results in a safe level in TL3 prey fish (150-350 mm length) of 0.17 mg/kg, which is above the proposed target for large TL3 fish.

Wildlife targets for TL3 and TL4 fish greater than 150 mm in length may be directly compared with targets developed to protect human consumers, as discussed in the following section. In Section 4.7, the wildlife and human targets that are trophic level and size-specific are incorporated into a single target based on largemouth bass that is protective of humans and all wildlife species of concern.

4.6 Human Health Targets

Numeric targets can be developed to protect humans in a manner analogous to targets for wildlife. A reference dose, average body weight and consumption rates are used along with Equations 4.1 and 4.3 to calculate safe fish tissue levels. In this section, the human health exposure parameters are discussed.

4.6.1 Acceptable Daily Intake Level

Central Valley Water Board staff used the USEPA RfD for methylmercury (USEPA, 2001) in Delta target calculations. The adverse effect level is based upon results of tests of neuropsychological function in children in the Faroe Islands exposed to methylmercury in fish. The USEPA incorporated a composite uncertainty factor of 10 for a final RfD of 0.1 µg methylmercury/kg bwt/day (USEPA, 2001). The USEPA describes its RfD as an estimate of a daily exposure level to humans that is likely to be without an appreciable risk of deleterious effect during a lifetime. The USEPA RfD is applied to the general population.[16]

4.6.2 Body Weight & Consumption Rate

This report uses the USEPA's standard adult bodyweight of 70 kg. Using an average pregnant female bodyweight (65 or 67 kg) would have very little difference on the calculation of mercury targets in fish.

Consumption rate is the most difficult of the fish tissue target variables to define because human consumption patterns are variable. The amount of methylmercury ingested is highly dependent on the amount of fish and the sizes and species of fish consumed. The desired level of fishing and consuming from the Delta lies somewhere between the limited amount recommended in the existing fish advisory and a probable upper bound of a very high consumer (i.e., the 99th percentile in United States consumption studies). People could eat unlimited quantities of fish from the Delta only if the fish mercury concentration was reduced to zero. Beneficial use protection in the case of mercury pollution, therefore, must be accomplished by a combination of cleanup and education. Education is a needed part of a TMDL implementation plan until effects of all mercury reduction efforts are reflected in fish tissue levels. During the implementation period, education is needed to encourage consumers to eat smaller fish and species with lower mercury concentrations.

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[16] "In the studies so far published on subtle neuropsychological effects in children, there has been no definitive separation of prenatal and postnatal exposure that would permit dose-response modeling. That is, there are currently no data that would support the derivation of a child (versus general population) RfD. This RfD is applicable to the lifetime daily exposure for all populations, including sensitive subgroups. It is not a developmental RfD per se, and its use is not restricted to pregnancy or developmental periods" *Water Quality Criterion for Methylmercury, Section 4-6* (USEPA 2001).

The California Department of Health Services has interviewed members of sub-populations thought to have high consumption rates (CDHS, 2004). However, a comprehensive survey of consumption of fish from the Delta has not been conducted. The USEPA recommends default consumption rates for the general population and various subpopulations (USEPA, 2001). Default consumption rates are derived from data collected nationwide as part of the 1994-96 USDA Continuing Survey of Food Intake by Individuals (CFSII). The USEPA reports rates separately for consumption of freshwater and marine fish. The USEPA recommends a default fish intake rate of 17.5 g/day (about one 8-ounce meal every two weeks[17]) to adequately protect the general population consuming freshwater and estuarine fish. This value represents the 90th percentile consumption rate for all survey participants, including those who do not eat fish. In selecting the 90th percentile, rather than the mean or median, the USEPA intended to recommend a consumption rate that is protective of the majority of the entire population. The USEPA recommended a consumption rate of 142.4 g/day (four to five fish meals per week) of local fish for the development of a human health criterion for anglers whose main source of protein is from locally caught fish. This value represents the 99th percentile consumption rate for all survey participants.

A detailed survey of consumption by anglers in San Francisco Bay was conducted in 1998 and 1999 (SFEI, 2000). The consumption rates for the 90th and 95th percentiles of anglers that were "consumers" (consumed Bay fish at least once prior to the interview) were 16 and 32 g/day, respectively. The San Francisco Bay Mercury TMDL selected the consumption rate for the 95th percentile of anglers (32 g/day) for calculation of the San Francisco Bay fish mercury target (0.2 mg/kg) to protect people who choose to eat San Francisco Bay fish on a regular basis (Johnson & Looker, 2004).

4.6.3 Consumption of Fish from Various Trophic Levels & Sources

Species and size of fish as well as consumption rate affect methylmercury intake. It is difficult to estimate amounts of various species of sport fish that might be consumed from the Delta. Based on the CSFII national survey, the USEPA assumed that on average, humans eat freshwater and estuarine fish from trophic levels two (3.8 g/day), three (8.0 g/day) and four (5.7 g/day) (USEPA, 2001). These rates are 21.7, 45.7, and 32.6% of the total 17.5 g/day, respectively. Trophic level 2 species, such as clams, shrimp and shimofuri goby, are harvested from the Delta for human consumption (Appendix C). However, CDFG creel surveys (CDFG, 2000-2001) and anecdotal information provided by CDFG staff (Schroyer, 2003) indicate that many Delta anglers are unlikely to take home TL2 species. As described in Figure C.1 in Appendix C, the creel surveys indicate that Delta anglers may target an almost even mix of TL3 (American shad, salmon, sunfish, splittail) and TL4 (catfish and striped bass) fish in the Sacramento and Mokelumne Rivers subareas of the Delta, and primarily TL4 species (striped bass and catfish) throughout the rest of the Delta. However, anecdotal information provided by CDFG staff (Schroyer, 2003) indicates that many Delta anglers take home a mix of TL3 and TL4 fish species.

Many fish consumers eat a combination of locally caught and commercially bought fish. When determining safe levels of consumption of Delta fish, the intake of methylmercury from commercial fish should be taken into account (see definition of RSC in Section 4.4). Based on the national CFSII survey, the USEPA assumes an average consumption rate of commercial fish of 12.46 g/day, which results in an

[17] Although the target calculations use bodyweights and consumption rates for adult humans, the resulting fish tissue levels protect children as well. Children's bodyweights and smaller portion sizes can also be fitted into Equations 4.1 and 4.3. The OEHHA has published a table of sizes of typical meals of fish that correspond to smaller bodyweights (OEHHA, 1999). Children would only be at risk of mercury toxicity if they consumed more than the average portion for their body size.

average daily intake of 0.027 µg methylmercury/kg bwt-day (USEPA, 2001). For people eating fish from commercial markets and the Delta, the safe intake level of methylmercury from Delta fish is the reference dose minus the methylmercury from commercial fish (0.1 µg/kg-day minus 0.027 µg/kg-day equals 0.073 µg/kg-day).[18]

4.6.4 Safe Rates of Consumption of Delta Fish

The USEPA issued a recommended methylmercury criterion of 0.3 mg/kg (rounded from 0.29 mg/kg[19]) in fish consumed by humans (USEPA, 2001). The USEPA human health criterion was calculated using a default consumption rate of freshwater/estuarine fish of 17.5 g/day (about one meal every two weeks) and commercial (marine) fish of 12.46 g/day, as derived from national dietary surveys described above (USEPA, 2001). The criterion assumed that on average, humans eat freshwater and estuarine fish from TL2 (21.7%), TL3 (45.7%) and TL4 (32.6%). However, the 2001 Water Quality Criterion report noted that the criterion can be adjusted on a site-specific or regional basis to reflect regional or local conditions and/or specific populations of concern. These include the consumption rates of local fish and the RSC estimate. The report also noted that States also can choose to apportion an intake rate to the highest trophic level consumed for their population or modify EPA's default intake rate based on local or regional consumption patterns. For example, the San Francisco Bay mercury target of 0.2 mg/kg was calculated using a consumption rate of 32 g/day (about one meal per week) derived from a San Francisco Bay consumption survey. The San Francisco Bay mercury target was applied to a single TL4 species, striped bass, because Bay-area consumers favor striped bass and striped bass contain relatively high mercury concentrations (Johnson & Looker, 2004; SFEI, 2000).

In the absence of Delta-specific consumption rates, the USEPA default consumption rate (17.5 g/day), San Francisco Bay consumption rate (32 g/day), and USEPA recommended consumption rate for anglers whose main source of protein is from locally caught fish (142.4 g/day) were used in Equation 4.1 to estimate the safe methylmercury level in the total diet for humans consuming Delta fish (Table 4.5). In addition, scenarios were developed for anglers that consume Delta and commercial fish, and for anglers that consume only Delta fish. For each of the total diet safe levels associated with the different consumption rates, three different distributions of locally caught fish were considered.

Equation 4.3 was used to develop safe levels for each trophic level of Delta fish. In order to solve Equation 4.3 for the desired concentrations in TL2, TL3 and TL4 biota, concentrations in the higher trophic levels are put in terms of the concentration in the lowest trophic level. Equation 4.3 is then rearranged to solve for the lowest trophic level concentration. In order to express the concentration in a higher trophic level, trophic level ratios were used. The TLRs used in the calculation of Delta human targets are shown in Table 4.6. Existing Delta fish concentration data were used to develop the ratios. The following example illustrates how the trophic level fish targets were developed for Scenario A.1 in Table 4.5 using Equations 4.1 and 4.3.

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[18] Most commercial fish do not come from the Delta. The most popular fish and seafood bought in commercial markets are marine species such as scallops, shrimp, and tuna. The average consumption rate of marine fish reported by all respondents in the national CFSII survey was 12.46 g/day (three meals every two months; USEPA, 2001). The average concentration of methylmercury in commercial species weighted by frequency of consumption is 0.16 mg/kg (USEPA, 2001; see also www.cfsan.fda.gov/seafood1.html.)

[19] The USEPA rounded from 0.288 mg/kg to 0.3 mg/kg for use as its recommended methylmercury criterion. Central Valley Water Board staff's calculations throughout the rest of this report are rounded to two decimal places, e.g., 0.29 mg/kg.

Per Equation 4.1:

$$\text{Safe MeHg in total diet of Delta fish} = \frac{\text{(Human RfD - Relative source contribution) * Body weight}}{\text{Consumption rate}}$$

$$0.29 \text{ mg/kg} = \frac{0.073\ \mu\text{g MeHg/kg-day} * 70 \text{ kg}}{17.5 \text{ g/day}}$$

Per Equation 4.3:

$$0.29 \text{ mg/kg} = (\%\ \text{dietTL}_2 * \text{TL3}_{conc}) + (\%\ \text{dietTL}_3 * \text{TL3}_{conc}) + (\%\ \text{dietTL}_4 * \text{TL4}_{conc})$$

Where: $\text{TL3}_{conc} = \text{TL2}_{conc} * \text{TLR } 3/2$

$\text{TL4}_{conc} = \text{TL2}_{conc} * \text{TLR } 3/2 * \text{TLR } 4/3$

$$0.29 \text{ mg/kg} = (21\% * \text{TL2}_{conc}) + (46\% * \text{TL2}_{conc} * 4.5) + (33\% * \text{TL2}_{conc} * 4.5 * 2.9)$$

Solving for TL2_{conc}:

$\text{TL2}_{conc} = 0.30 / (0.21 + (0.45*4.5) +(0.33*4.5*2.9)) = 0.046$ mg/kg in shrimp & clams

$\text{TL3}_{conc} = 0.046 \text{ mg/kg} * 4.5 = 0.20$ mg/kg in 150-500 mm fish

$\text{TL4}_{conc} = 0.046 \text{ mg/kg} * 4.5 * 2.9 = 0.45$ mg/kg in 150-500 mm fish

As indicated by Table 4.5, potential safe levels of mercury in large Delta TL4 fish range from 0.05 to 0.80 mg/kg, depending on the assumed trophic level distribution of locally caught fish and the amount of Delta and commercial fish consumed. The highlighted safe levels for TL3 and TL4 fish developed by Scenarios A.1, A.3, B.2 and E.3 are evaluated as water quality objective alternatives in Chapter 3 of the Proposed Basin Plan Amendment draft staff report. The TL3 and TL4 targets produced by Scenario B.2 of 0.08 mg/kg and 0.24 mg/kg, respectively, are recommended by Central Valley Water Board staff for the protection of humans who consume fish from throughout the Delta because they are protective of a higher consumption rate than that used to develop the USEPA criterion and because available information indicates that anglers take home a mixture of TL3 and TL4 species. These targets are carried forward throughout the rest of this report for use in the food web evaluation, linkage analysis and development of methylmercury source allocations. Central Valley Water Board staff will update the calculations presented in Table 4.5 as Delta-specific consumption information becomes available.

Table 4.5: Safe Concentrations of Methylmercury in Delta Fish by Trophic Level (TL) to Protect Humans Calculated Using Varying Assumptions about Consumption Rates and Trophic Level Distribution

Scenario	Body Weight (kg)	Acceptable Daily Delta Fish MeHg Intake Level (µg/kg-day) (a)	Total Consumption Rate of Delta Fish (g/day) (b)	Safe MeHg Level in Total Diet of Delta Fish (mg/kg) (c)	Distribution of Locally Caught Fish by TL			Safe Concentration of MeHg in Fish by TL (mg/kg) (d)		
					TL2	TL3	TL4	TL2	TL3	TL4
For people eating commercial and Delta fish:										
A.1	70	0.073	17.5	0.29	21.7%	45.7%	32.6%	0.04	**0.20**	**0.58**
A.2					---	50%	50%		0.15	0.43
A.3					---	---	100%			**0.29**
B.1	70	0.073	32	0.16	21.7%	45.7%	32.6%	0.02	0.11	0.32
B.2					---	50%	50%		**0.08**	**0.24**
B.3					---	---	100%			0.16
For people eating only Delta fish:										
C.1	70	0.1	17.5	0.40	21.7%	45.7%	32.6%	0.06	0.28	0.80
C.2					---	50%	50%		0.21	0.59
C.3					---	---	100%			0.40
D.1	70	0.1	32	0.22	21.7%	45.7%	32.6%	0.03	0.15	0.44
D.2					---	50%	50%		0.11	0.33
D.3					---	---	100%			0.22
E.1	70	0.1	142.4	0.05	21.7%	45.7%	32.6%	0.01	0.03	0.10
E.2					---	50%	50%		0.03	0.07
E.3					---	---	100%			**0.05**

(a) For people eating fish from commercial markets and the Delta, the safe intake level of methylmercury from Delta fish is the USEPA reference dose minus the methylmercury from commercial fish (0.1 µg/kg-day minus 0.027 ug/kg-day = 0.073 ug/kg-day). Scenarios C through E assume no commercial fish are consumed.

(b) The USEPA human health criterion was calculated using a default consumption rate of freshwater/estuarine fish of 17.5 g/day and of commercial (marine) fish of 12.46 g/day, as derived from national dietary surveys (USEPA, 2001). The criterion assumed that on average, humans eat freshwater and estuarine fish from TL2 (21.7%), TL3 (45.7%) and TL4 (32.6%).

(c) The USEPA criterion calculations yielded a methylmercury value of 0.288 mg methylmercury/kg fish, which the USEPA rounded to one significant digit. The Region 2 San Francisco Bay Mercury TMDL target calculations yielded a methylmercury value of 0.16 mg methylmercury/kg fish, which Region 2 also rounded to one significant digit in the San Francisco Bay Mercury TMDL report (Johnson & Looker, 2004).

(d) Values were calculated using Equation 4.3 and trophic level ratios presented in Table 4.6. Values were rounded to two decimal places. The highlighted targets (Scenarios A.1, A.3, B.2 and E.3) are evaluated as water quality objective alternatives in the Proposed Basin Plan Amendment draft staff report. The TL3 and TL4 targets produced by Scenario B.2 are recommended for the protection of humans that consume fish from throughout the Delta and are carried forward throughout the rest of this report for use in the linkage analysis and development of allocations.

Table 4.6: Trophic Level Ratios for Delta Human Target Development

Translator	Value	Source
TLR 4/3	2.9	Ratio between existing MeHg concentrations in large TL4 fish (150 mm [or legal catch limit] to 500 mm length) and large TL3 fish (150 mm [or legal catch limit] to 500 mm length). Calculated from Delta-wide average fish tissue levels; see Appendix B.
TLR 3/2	4.5	Ratio between existing MeHg concentrations in large TL3 fish (150-500 mm length) and TL2 species potentially consumed by humans (shrimp and clams). Calculated from Delta-wide average fish tissue levels; see Appendices B, C and L.

4.7 Trophic Level Food Group Evaluation

As noted in the previous section, Central Valley Water Board staff recommends targets of 0.08 and 0.24 mg/kg in large TL3 and TL4 fish, respectively, for the protection of humans that consume fish from throughout the Delta. In this section, the relationships between methylmercury concentrations in large TL4 fish and the other trophic level food groups are examined. The purpose of this analysis is to determine whether consistent relationships might exist between the assemblages of fish and, if so, whether it might be possible to describe safe mercury ingestion rates for humans and wildlife species in terms of large TL4 fish. This analysis enables staff to determine whether a water quality objective based on methylmercury in large fish developed for the protection of humans may or may not be protective of wildlife species that consume smaller or lower trophic level fish.

4.7.1 Data Used in Trophic Level Food Group Evaluation

Mercury concentrations for each trophic level food group sampled in the Delta are summarized in Table 4.7. Values presented are average concentrations, weighted by the number of individual fish in composite samples. The trophic level food group concentrations are the result of analyzing 1,048 composite samples of 4,578 fish from 23 species in the Delta (Table B.2 and B.3 in Appendix B). Figure 4.1 illustrates the fish sampling locations used in the trophic level food group evaluation. The sampling was conducted by CDFG, SFEI, University of California, Davis, the Toxic Substances Monitoring Program, and the Sacramento River Watershed Program (Davis *et al.*, 2000; Davis *et al.*, 2003; Slotton *et al.*, 2003; LWA, 2003; SWRCB-DWQ, 2002).

The data for each food group were assembled after considering four general rules. First, the data were restricted to samples collected between 1998 and 2001, the period with the most comprehensive sampling across the Delta. Second, migratory species (salmon, American shad, steelhead, sturgeon, striped bass) were excluded. These species likely do not reside year-round at the locations in the Delta where they were caught and their tissue mercury levels may not show a positive relationship with the mercury levels in resident animals. In addition, data for migratory species are not available for all Delta subareas, precluding an analysis to determine whether such a relationship might exist. A review of data available for several commercial species (striped bass, salmon, blackfish and crayfish) is provided in Appendix C.[20]

[20] Methylmercury concentrations in salmon and striped bass are important to human risk assessment because people frequently attempt to catch these two species. Average mercury concentrations in striped bass are similar to mercury levels in largemouth bass. The available mercury data for salmon indicate that their tissue concentrations are much lower that the mercury levels in bass (0.04 to 0.12 mg/kg). See Appendix C for more information about striped bass and salmon.

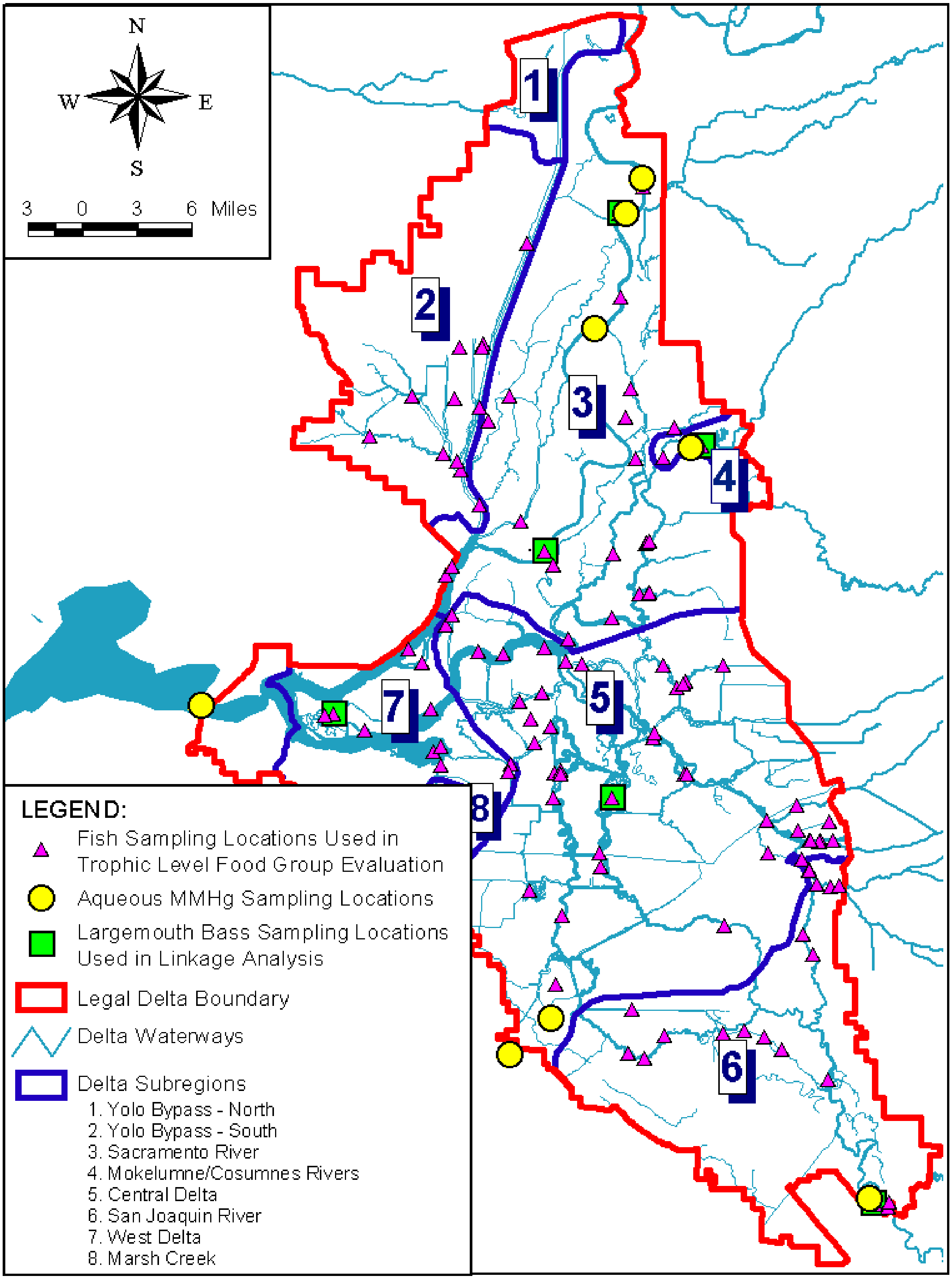

Figure 4.1: Fish & Water Sampling Locations Included in the Trophic Level Food Group and Largemouth Bass Evaluations.

Table 4.7: Mercury Concentrations in Trophic Level Food Groups Sampled in the Delta

Trophic Level Food Group	Hg Concentrations (mg/kg) by Delta Subarea (a)				
	Central Delta	Mokelumne River	Sacramento River	San Joaquin River	West Delta
TL4 Fish (150-500 mm)	0.26	0.92	0.56	0.50	0.32
TL3 Fish (150-500 mm)	0.08	0.28	0.21	0.11	0.11
TL4 Fish (150-350 mm)	0.20	0.75	0.46	0.42	0.24
TL3 Fish (150-350 mm)	0.08	0.29	0.17	0.12	0.08
TL3 Fish (50-150 mm)	0.03	0.09	0.04	0.04	0.03
TL3 Fish (<50 mm)	0.02	0.07	0.03	0.04	0.03

(a) The trophic level food group mercury levels are weighted averages of mercury levels for resident fish within each food group collected in each Delta subarea between 1998 and 2001. These food groups correspond to the proposed numeric targets developed earlier in Chapter 4. Weighted average mercury concentration is based on the number of fish in the composite samples analyzed, rather than the number of samples.

Third, fish samples with lengths greater than 500 mm were not included. Data for fish larger than 500 mm are available for only some subareas. Capping the size at 500 mm allows comparable data for all Delta subareas. Finally, only fish fillet data were used in the human and eagle trophic level food group analysis. Humans typically consume fish fillets, while wildlife species, including eagles, eat whole fish. However, all the data for large fish typically consumed by eagles and other large wildlife species are from fillet samples, making it necessary to use fillet information for these species.[21] Whole fish data were used for the smaller wildlife species food groups.

Of the eight Delta subareas identified in Section 2.2.2 and Figure 2.2, three of the subareas were not included in the trophic level food group evaluation due to inadequate information. No fish were sampled from the Marsh Creek subarea between 1998 and 2001. In addition, small fish were sampled throughout the Yolo Bypass-South subarea between 1998 and 2001, but large fish were sampled only in the southernmost area; hence, the mercury levels in the trophic level food groups are not geospatially comparable. The only fish sampling conducted in the Yolo Bypass-North subarea took place in Greens Lake, which is not considered representative of the entire subarea. In addition, only large TL4 fish were sampled; no small fish were sampled.

Table 4.8 provides a comparison of the average mercury concentrations for each trophic level food group sampled in the Delta (Table 4.7) to the recommended targets for the species with the lowest safe fish methylmercury levels within each trophic level food group. The comparison indicates that the recommended targets for wildlife protection are already met in the Central and West Delta subareas. In addition, the comparison indicates that greater reductions may be required to achieve the recommended target for large TL4 fish developed for human protection than for the recommended targets for smaller

[21] Researchers in New York found that concentrations in whole body and muscle of large TL3 and TL4 fish were not significantly different (Becker and Bigham, 1995), suggesting that it is appropriate to use fillet data to evaluate exposure to wildlife species.

and lower trophic level fish developed for wildlife protection. The following section describes a more direct method for comparing the level of protection provided by the different trophic level food group targets.

Table 4.8: Percent Reductions in Fish Methylmercury Levels Needed to Meet Numeric Targets

Trophic Level Food Group	Target Species (a)	Target (mg/kg)	Delta Subareas				
			Central Delta	Mokelumne River	Sacramento River	San Joaquin River	West Delta
TL4 Fish (150-500 mm)	Human	0.24	8%	74%	57%	52%	25%
TL3 Fish (150-500 mm)	Human	0.08	0%	71%	62%	27%	27%
TL4 Fish (150-350 mm)	Osprey	0.26	0%	65%	43%	38%	0%
TL3 Fish (150-350 mm)	Grebe	0.08	0%	72%	53%	33%	0%
TL3 Fish (50-150 mm)	Kingfisher	0.05	0%	44%	0%	0%	0%
TL3 Fish (<50 mm)	Least Tern	0.03	0%	57%	0%	25%	0%

(a) Only the recommended targets for the wildlife species with the lowest safe methylmercury concentrations in fish diet (Table 4.3) within each trophic level food group are evaluated. The proposed large TL3 and TL4 fish targets for human protection are lower than the targets proposed for protection of eagles.

4.7.2 Trophic Level Food Group Comparisons

Regressions between methylmercury concentrations in large TL4 fish and the other TL food groups are presented in Figure 4.2. The relationships were evaluated using linear, exponential, logarithmic and power curves; in each case the type of curve that provided the highest R^2 value was selected. All of the correlations were statistically significant ($P<0.05$ or less). The regressions demonstrate that there are predictable relationships between mercury concentrations in large TL4 fish and the other trophic level food groups in the Delta.

Table 4.9 presents the predicted safe dietary mercury concentrations for each target species in terms of large TL4 fish calculated from the regression equations in Figure 4.2. The target of 0.24 mg/kg in large TL4 fish developed for the protection of humans is lower than the corresponding safe large TL4 fish mercury concentrations predicted for the other TL food groups, which ranged from 0.30 mg/kg for Western grebe to 1.12 mg/kg for Western snowy plover. This indicates that the large TL3 and TL4 fish targets developed for protection of humans are most likely protective of wildlife species that consume smaller or lower trophic level fish. In other words, reductions in methylmercury levels needed to achieve the target for large TL3 and TL4 fish are expected to produce reductions in smaller fish sufficient to fully protect wildlife species. To ensure that wildlife species dining only on small fish are protected, staff proposes an additional target of 0.03 mg/kg methylmercury in TL2 and 3 fish less than 50 mm in length. This target represents the safe level for prey consumed by the California least tern, a piscivorous species listed by the federal government as endangered. As shown in Table 4.9, such a target for small fish also would protect the Western snowy plover.

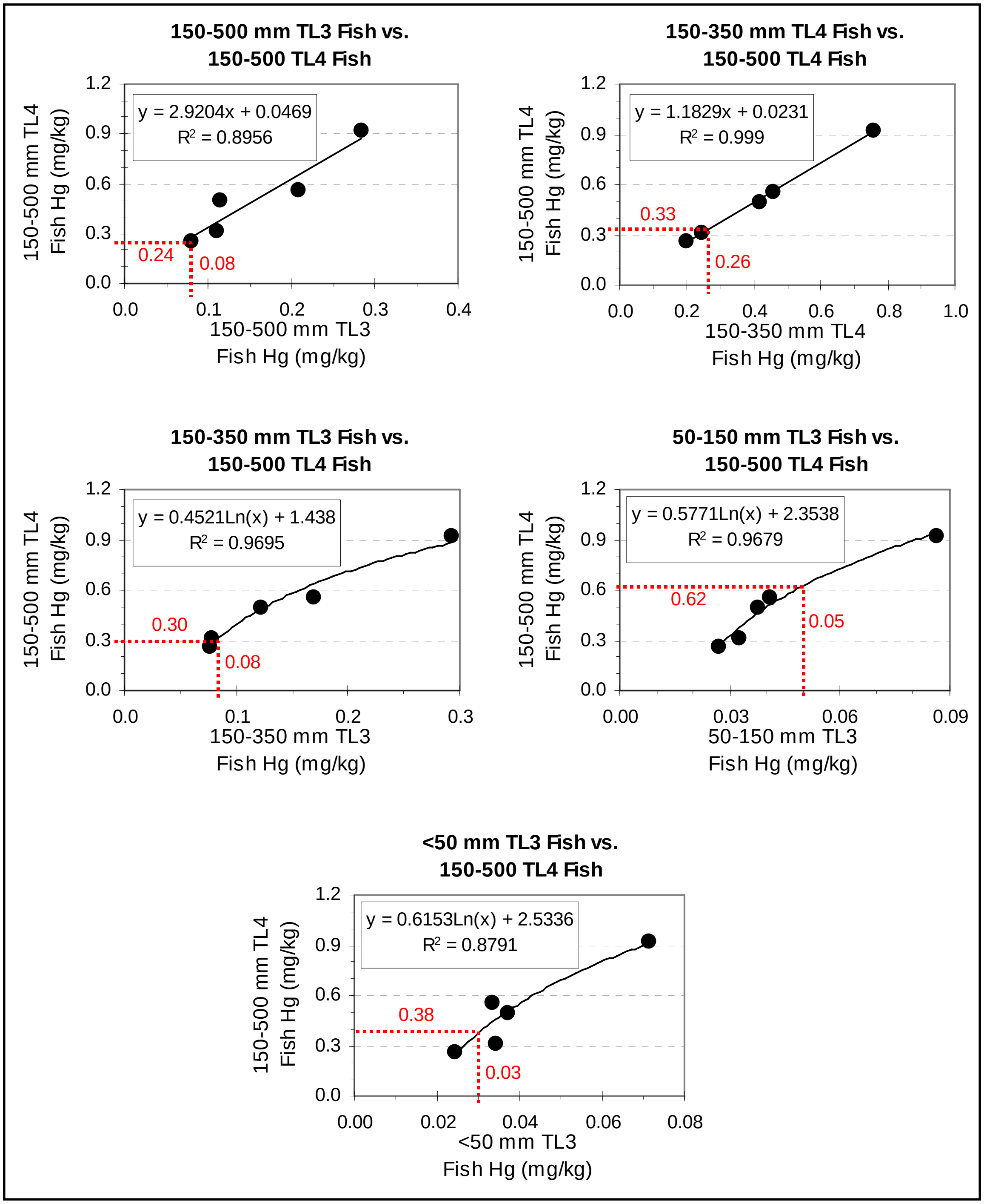

Figure 4.2: Comparison of Methylmercury Concentrations in Large (150-500 mm) TL4 Fish and Other Trophic Level (TL) Food Groups. The regressions are used to predict safe diets for target species listed in Table 4.9 in terms of large TL4 fish.

Table 4.9: Predicted Safe Concentrations of Methylmercury in 150-500 mm TL4 Fish and Standard 350-mm Largemouth Bass Corresponding to Trophic Level Food Group (TLFG) Targets for the Protection of Piscivorous Species.

Trophic Level Food Group / Species	**TLFG Target** (mg/kg) (a)	**Predicted 150-500 mm TL4 Fish Safe Level** (mg/kg)	**Predicted Standard 350-mm Largemouth Bass Safe Level** (mg/kg) (b)
TL4 Fish (150-500 mm)			
Human	0.24	(c)	0.28
Bald eagle	0.31	(c)	0.36
TL3 Fish (150-500 mm)			
Human	0.08	0.24	0.24
Bald eagle	0.11	0.37	0.43
TL4 Fish (150-350 mm)			
Osprey	0.26	0.33	0.36
River otter	0.36	0.45	0.57
TL3 Fish (150-350 mm)			
Western grebe	0.08	0.30	0.31
Common merganser	0.09	0.35	0.38
Osprey	0.09	0.35	0.38
TL3 Fish (50-150 mm)			
Kingfisher	0.05	0.62	0.73
Mink	0.08	0.90	1.06
River otter	0.04	0.50	0.57
Double-crested cormorant	0.09	0.96	1.15
TL3 (<50 mm)			
California least tern	0.03	0.38	0.42
Western snowy plover	0.10	1.12	1.34

(a) The TLFG targets developed for bald eagle, osprey and river otter were developed using site-specific TLRs and/or FCMs combined with information provided in published literature. All other TLFG targets were entirely developed using information provided in published literature.
(b) The calculation and purpose of the standard 350-mm largemouth bass mercury concentrations are described in the following section (Section 4.8).
(c) The TL4 Goals are same as the TLFG Targets for human and eagle protection.

4.8 Largemouth Bass Evaluation

A goal of the TMDL is to link target methylmercury concentrations in fish to methylmercury concentrations in water to develop a goal for aqueous methylmercury that could then be used in development of an implementation plan. Chapter 5 (Linkage Analysis) describes the relationships between methylmercury in water and in largemouth bass in the Delta. Largemouth bass were selected for the linkage analysis for several reasons. Largemouth bass are a good bioindicator species. In addition, only largemouth bass data are available for the same sampling period and locations as the methylmercury water data (Figure 4.1). Largemouth bass, however, constitute only a portion of the diet of some of the human and wildlife consumers of Delta fish. The methylmercury targets determined above assume that humans and wildlife species consume a variety of sizes and species of fish from the Delta. In this section, the relationships between methylmercury concentrations in largemouth bass and the trophic level food groups were examined so that an implementation goal could be developed in terms of largemouth bass and, ultimately, linked to aqueous methylmercury.

Most of the information on mercury concentrations in the various trophic level food groups in the Delta was collected as species-specific composite samples between 1998 and 2001. Therefore, the largemouth bass evaluation was conducted in four parts. First, the methylmercury concentrations in largemouth bass of a standard size were estimated for each Delta subarea using the relationships between length and methylmercury tissue concentration[22] in samples collected in 2000. Second, correlations were run between standard 350-mm largemouth bass collected in 2000 and average concentrations of 300-400 mm largemouth bass (composite and individual samples) collected between 1998 and 2000. The year 2000 is significant because (1) aqueous methylmercury sampling began in March 2000 and (2) largemouth bass sampling adequate for the length/concentration regressions took place only in September/October 2000. The monthly March-October 2000 subset of the aqueous data has the greatest overlap with the lifespan of the largemouth bass sampled in September/October 2000. As these correlations were highly significant, the third step was to examine correlations between mercury concentrations in standard 350-mm largemouth bass and composites of all trophic level food groups collected in the Delta between 1998 and 2001. The purpose of this analysis was to determine whether consistent relationships might exist between the different assemblages of fish and, if so, whether it might be possible to describe safe mercury ingestion rates for humans and wildlife species in terms of the methylmercury concentration in a standard 350-mm largemouth bass. The final step was to determine a safe methylmercury concentration for each species in terms of the methylmercury concentration in 350-mm largemouth bass (Table 4.9).

4.8.1 Largemouth Bass Standardization

The methylmercury content of a standard 350-mm length largemouth bass was determined at all sites where both water and fish tissue data were available (Figure 4.1) by regressing fish length against mercury body burden (Figure 4.3). Table 4.10 presents the predicted mercury values for 350 mm bass at each location. The predicted mercury concentration in standard 350 mm largemouth bass varied by a factor of five across the Delta (0.19 mg/kg in the Central Delta to 1.04 mg/kg in the Mokelumne River). Mercury concentration in a standard length 350 mm largemouth bass was selected because the length is near the middle of the size range collected at each site and therefore maximizes the predictive capability of the regression (Davis and Greenfield, 2002). Three hundred and fifty mm is slightly larger than CDFG's legal size limit of 305 mm (12 inches). A 350 mm bass is three to five years old (Shaffter, 1998; Moyle, 2002).

[22] Determining the methylmercury concentration in a specific or "standard" size fish is a typical method of data analysis that allows comparison between sites and years. For largemouth bass from one site or subarea, mercury concentration is well correlated with length (Davis & Greenfield, 2002; data in Figure 4.2). This correlation is also useful in monitoring, as concentrations in fish in a range of lengths can be used to predict the concentration in a standard size. Hereafter, the mercury concentration in a "standard 350 mm largemouth bass" refers to the concentration obtained through a regression analysis as in Figure 4.2.

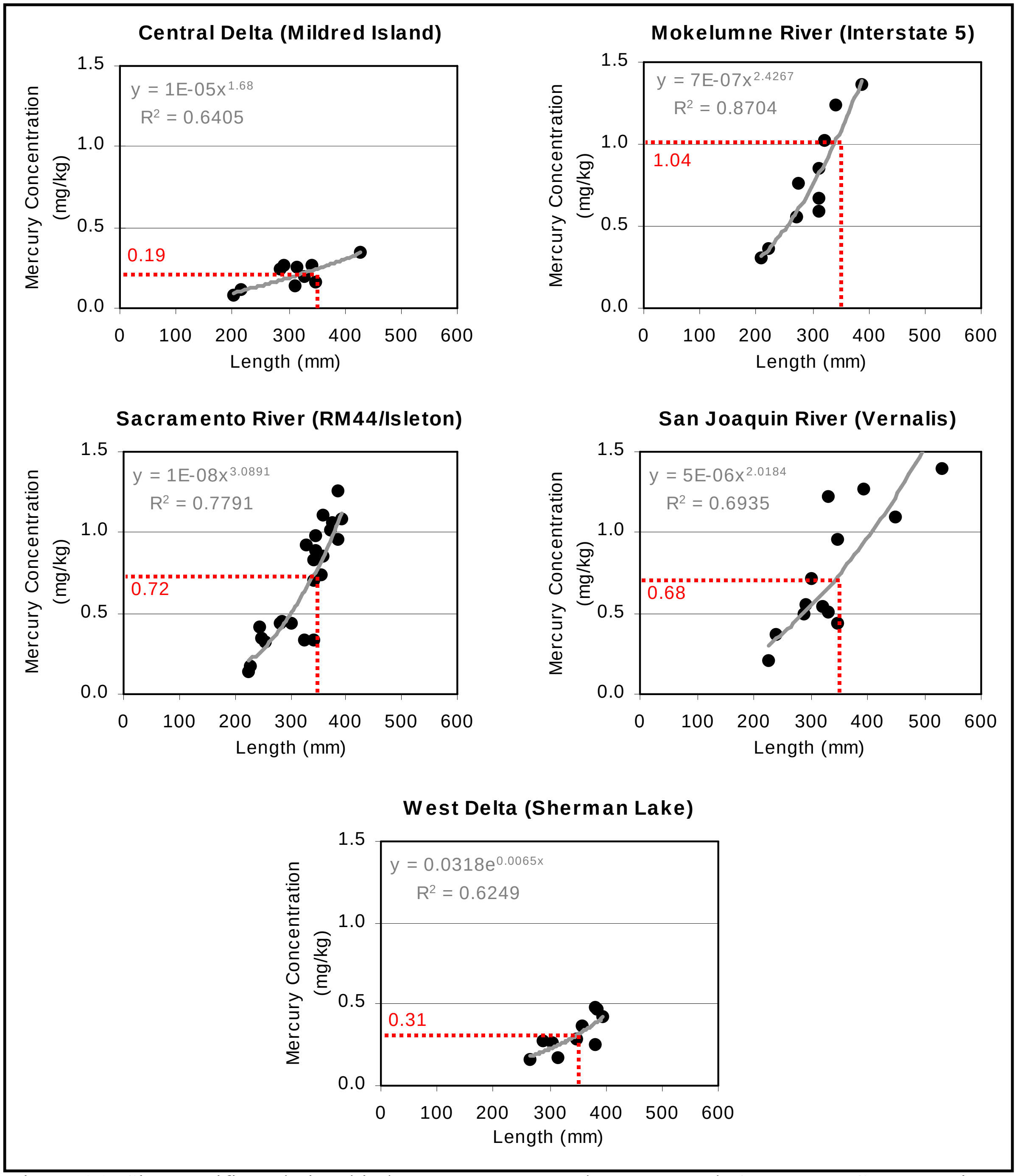

Figure 4.3: Site-specific Relationship between Largemouth Bass Length & Mercury Concentrations in the Delta. The relationships were used to predict the mercury content of a standard, 350-mm length bass sampled in September/October 2000, as indicated by the dashed lines. All relationships were significant at least at $P<0.05$.

4.8.2 Correlations between Standard 350 mm and All Largemouth Bass Data

Figure 4.4 presents the regression between mercury levels in standard 350-mm largemouth bass collected in year 2000 and weighted-average concentrations in 300-400 mm largemouth bass collected between 1998 and 2000 in five delta subareas[23] (Table 4.10). Each data point represents one subarea. The correlation is statistically significant (P<0.01) and has a slope of 0.8, suggesting that mercury concentrations do not vary appreciably between the two groups. The results suggest that year 2000 standard 350-mm bass mercury levels are representative of mercury concentrations in largemouth bass collected between 1998 and 2000.

Table 4.10: Mercury Concentrations in Standard 350-mm & 300-400 mm Largemouth Bass

	Hg Concentrations (mg/kg) by Delta Subarea				
	Central Delta	Mokelumne River	Sacramento River	San Joaquin River	West Delta
Year 2000 Standard 350-mm largemouth bass collected in September/October 2000 (a)	0.19	1.04	0.72	0.68	0.31
300-400 mm largemouth bass collected between 1998 and 2000 (b)	0.31	0.94	0.76	0.64	0.30

(a) The standard 350-mm largemouth bass mercury concentrations are predicted values derived using the regressions in Figure 4.3.
(b) The values for the 300-400 mm bass are weighted-average concentrations in 300-400 mm largemouth bass collected between 1998 and 2000 from multiple locations within each of the five delta subareas.

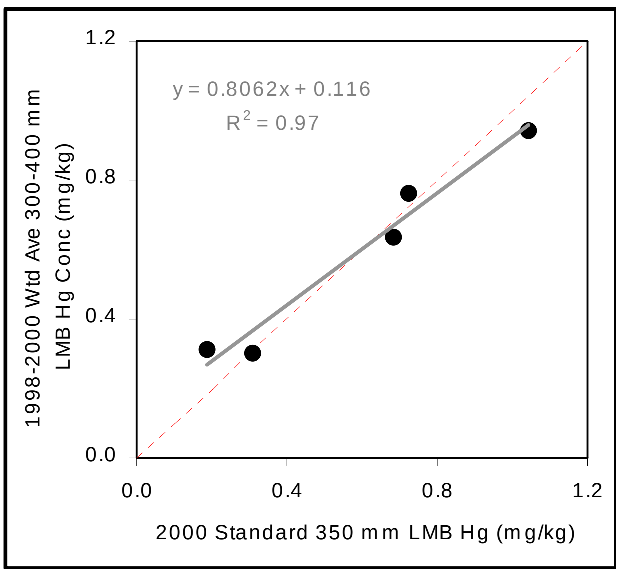

Figure 4.4: Comparison of Mercury Levels in Standard 350 mm Largemouth Bass (LMB) Collected at Linkage Sites in 2000 and Mercury Levels in 300-400 mm LMB Collected throughout Each Subarea in 1998-2000.

[23] Data collected in 1998-2000 contained individual and composite samples. Mercury concentrations in the composite samples were weighted by number of individual fish in the composite and then averaged with individual results.

4.8.3 *Largemouth Bass/Trophic Level Food Group Comparisons*

Regressions between mercury concentrations in standard 350-mm largemouth bass and TL3 and TL4 food groups are presented in Figure 4.5. The purpose of this analysis was to determine whether consistent relationships might exist between the different assemblages of fish and, if so, whether it might be possible to describe safe mercury ingestion rates for wildlife species and humans in terms of the mercury concentration in a standard 350-mm largemouth bass. The relationships were evaluated using linear, exponential, logarithmic and power curves; in each but one case the type of curve that provided the highest R^2 value was selected.[24] All of the correlations were statistically significant ($P<0.05$ or less). The regressions demonstrate that there are predictable relationships between mercury concentrations in standard 350-mm largemouth bass and all trophic level food groups in the Delta.

Table 4.9 presents the predicted safe dietary mercury concentrations for each target species in terms of standard 350-mm bass. The safe largemouth bass mercury levels were calculated from the regression equations in Figure 4.5. The lowest largemouth bass mercury value (0.24 mg/kg) corresponds to 0.08 mg/kg in 150-500 mm TL3 fish. This is the most conservative of all the calculated largemouth bass safe levels and, if attained, should fully protect all listed beneficial uses in the Delta. Staff recommends that **0.24 mg/kg, wet weight, in a standard 350-mm largemouth bass** be used as an **implementation goal** in the linkage analysis (Chapter 5) and determination of methylmercury allocations (Chapter 8).

As described in Tables 4.8 and 4.11, percent reductions in fish methylmercury levels ranging between 0 and 77% will be needed to meet the recommended numeric targets for large and small TL3 and TL4 fish and the implementation goal for standard 350-mm largemouth bass in the different Delta subareas. Staff expects that when methylmercury concentrations in largemouth bass reach the recommended implementation goal for standard 350-mm largemouth bass, then concentrations in other aquatic organisms also will have declined sufficiently to protect human and wildlife consumers. Monitoring should be conducted in all trophic level food groups at that time to verify that the expected decreases have occurred.

Key points and options to consider for the numeric targets are listed after Figure 4.5.

Table 4.11: Percent Reductions in Standard 350-mm Largemouth Bass Methylmercury Levels Needed to Meet the Recommended Implementation Goal of 0.24 mg/kg in Each Delta Subarea.

Central Delta	Mokelumne River	Sacramento River	San Joaquin River	West Delta
0%	77%	67%	65%	23%

[24] A logarithmic curve best fits the points comparing standard 350-mm largemouth bass mercury concentrations to 150-500 mm TL4 fish (Figure 4.3). However, the curve intercepts the x-axis well above zero, preventing the prediction of a standard largemouth bass mercury concentration that corresponds to the large TL4 fish mercury target developed for human protection (0.24 mg/kg), which is lower than average mercury concentrations observed in large Delta TL4 fish. Therefore, a linear equation with the intercept set to zero was used to estimate a standard 350-mm largemouth bass mercury concentration that corresponds to the large TL4 fish target. This regression was also statistically significant ($P<0.01$). However, use of the regression to predict a safe level for largemouth bass that corresponds to the TL4 target has additional uncertainty because the TL4 target of 0.24 mg/kg is slightly lower than the lowest (0.26 mg/kg in the Central Delta subarea) of observed values upon which the regression is based.

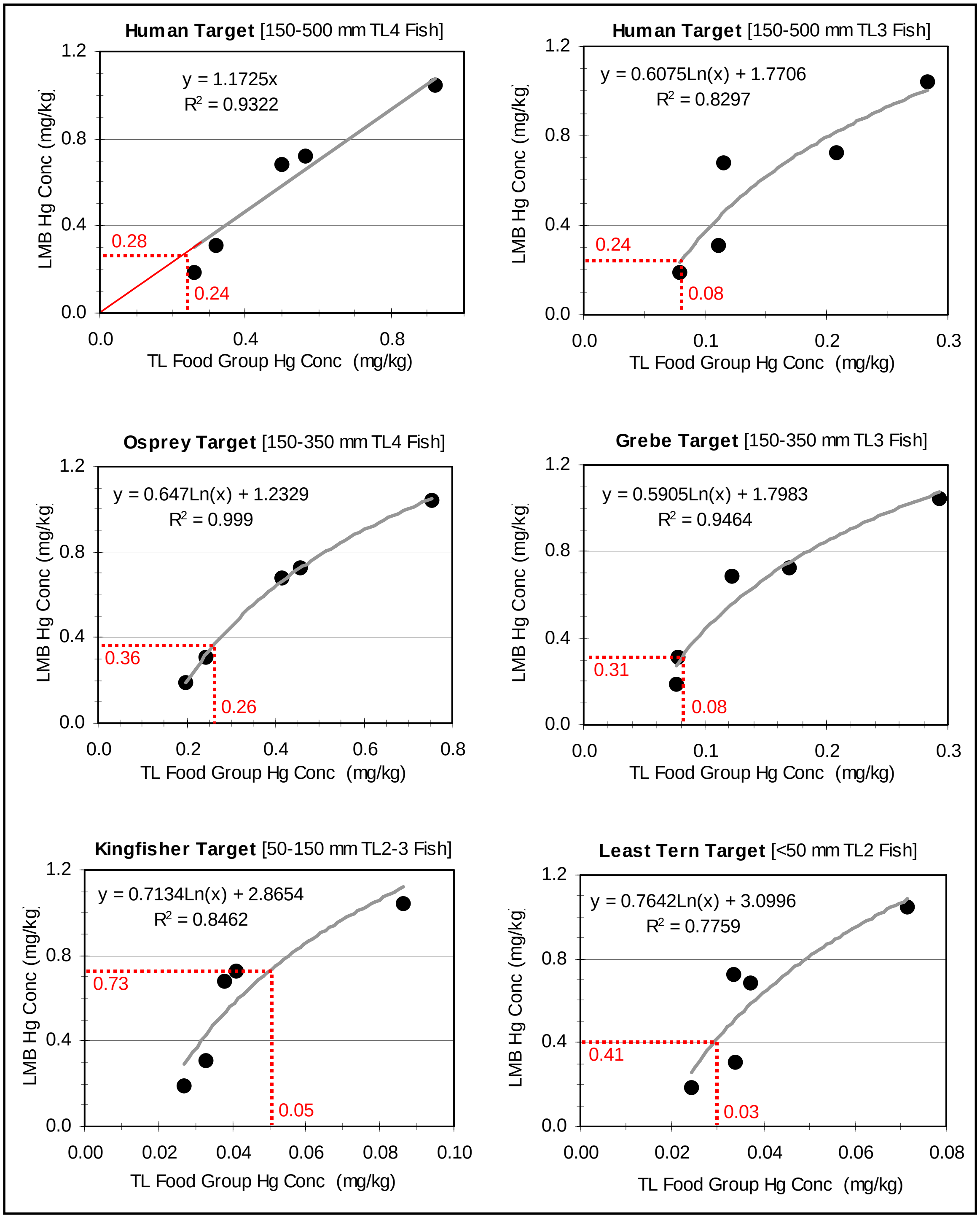

Figure 4.5: Comparison of Mercury Concentrations in Standard 350-mm Largemouth Bass (LMB) Caught in September/October 2000 and Composites of Fish from Various Trophic Level (TL) Food Groups Caught between 1998 and 2001. The regressions are used to predict safe diets for target species listed in Table 4.9 in terms of largemouth bass mercury concentrations. Note, the recommended target for large TL4 fish (0.24 mg/kg) developed for human protection is lower than average mercury levels observed in the Delta, resulting in a corresponding standard 350-mm largemouth bass concentration that falls slightly below the regression curve based on observed values.

Key Points

- The concentration of methylmercury in fish tissue is the numeric target selected for the Delta methylmercury TMDL. Measurements of mercury in fish should be able to assess whether beneficial uses are being met because fish-eating (piscivorous) birds and mammals are most likely at risk for mercury toxicity.
- Piscivorous species identified in the Delta are: American mink, river otter, bald eagle, kingfisher, osprey, western grebe, common merganser, peregrine falcon, double crested cormorant, California least tern, and western snowy plover. Bald eagles, California least terns and peregrine falcons are listed by the State of California or by USFWS as either threatened or endangered species.
- Acceptable fish tissue levels of mercury for the trophic level food groups consumed by each wildlife species were calculated using the method developed by USFWS that addresses daily intake levels, body weights and consumption rates. Numeric targets were developed to protect humans in a manner analogous to targets for wildlife using USEPA-approved methods and regional information.
- Central Valley Water Board staff recommends two numeric targets for large fish: 0.24 mg/kg (wet weight) in muscle tissue of large trophic level four (TL4) fish such as bass and catfish and 0.08 mg/kg (wet weight) in muscle tissue of large TL3 fish such as carp and salmon. These targets are protective of (a) humans eating 32 g/day (1 meal/week) of commonly consumed, large fish; and (b) all wildlife species that consume large fish. The evaluation of the relationships between methylmercury concentrations in large TL4 fish and the other trophic level food groups indicated that wildlife species that consume smaller or lower trophic level fish would be protected by the large TL3 and TL4 fish targets developed for human protection.
- To ensure that wildlife species dining only on small fish are protected, staff proposes an additional target of 0.03 mg/kg methylmercury in whole TL2 and 3 fish less than 50 mm in length. This target represents the safe level for prey consumed by the California least tern, a piscivorous species listed by the federal government as endangered. Such a target for small fish also would protect the Western snowy plover and other species that consume small fish.
- Elevated fish mercury concentrations occur along the periphery of the Delta while lower body burdens are measured in the central Delta. Percent reductions in fish methylmercury levels ranging from 0% to 74% will be needed to meet the numeric targets for wildlife and human health protection in all subareas of the Delta.
- The relationships between methylmercury concentrations in largemouth bass and the trophic level food groups also were examined because largemouth bass are a good bioindicator species and only largemouth bass data are available for the same sampling period and locations as the methylmercury water data available for the linkage analysis (next chapter). It was possible to describe safe mercury ingestion rates for wildlife species and humans in terms of the mercury concentration in a standard 350-mm largemouth bass. A methylmercury concentration of 0.24 mg/kg in 350-mm length largemouth bass would fully protect humans and piscivorous wildlife species and is proposed as an implementation goal for use in the linkage analysis and determination of methylmercury allocations for point and nonpoint sources.

Options to Consider

- A variety of assumptions can be made to calculate safe fish mercury levels for humans. For example, staff recommended targets of 0.08 mg/kg and 0.24 mg/kg for large TL3 and TL4 fish, respectively, because such targets are protective of a higher consumption rate (~1 meal/week) than that used to the develop the USEPA criterion (~1 meal/2 weeks) and because available information indicates that anglers take home a mixture of TL3 and TL4 species. Application of the USEPA criterion to large TL4 fish results in a target of 0.29 mg/kg. Use of the USEPA default consumption rates of fish from TL2 (21.7%), TL3 (45.7%) and TL4 (32.6%) produces a much higher target of 0.58 mg/kg for large TL4 fish. However, as the evaluations of trophic level food group and standard 350-mm largemouth bass mercury levels indicates, a target of 0.58 mg/kg for large TL4 fish would not protect several piscivorous wildlife species, such as bald eagle, osprey, river otter, grebe, merganser, and least tern. Large TL4 fish targets of 0.29 or 0.24 mg/kg would be protective of these species.